At Long Last, Gravity Probe B Satellite Proves Einstein Right

by Adrian Cho on 4 May 2011, 5:30 PM | Permanent Link | 0 Comments

Fifty years after it was conceived, a $760 million NASA spacecraft has confirmed Einstein's theory of gravity, or general relativity, physicists announced today. Gravity Probe B achieved measurements that agreed with theoretical predictions for two effects of general relativity, which states that gravity arises when mass bends space and time. "Einstein survives!" said Francis Everitt, a physicist at Stanford University in Palo Alto, California, who reported the results at a press conference at NASA headquarters in Washington, D.C.

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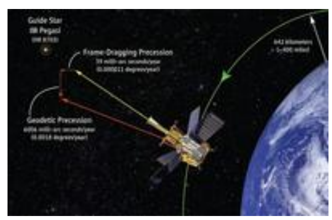

Wee wobbles. Gravity Probe B measured slight canting of the spins of gyroscopes to measure two effects of general relativity.

Credit: Bob Kahn/Gravity Probe B/Stanford University

Other researchers, however, greeted the results with what amounted to polite applause. Gravity Probe B fell well short of the precision developers had hoped to achieve in making the key measurement. Moreover, the project got scooped 6 years ago, when two physicists made a similar measurement using data from much cheaper satellites. "I have to compliment the Gravity Probe B team for their result, because Gravity Probe B is a very difficult and very beautiful experiment," says Ignazio Ciufolini, a physicist at the University of Salento in Lecce, Italy, who made the earlier measurement.

After decades of development, Gravity Probe B circled Earth from pole to pole for 17 months starting 20 April 2004 and used gyroscopes to measure two aspects of general relativity. One, the "geodetic effect," arises because Earth's mass creates a kind of dimple in spacetime that messes up the usual rules of geometry. As a result, the circumference of a circle around Earth should be slightly shorter than Euclid's value of 2π times the circle's radius. Gravity Probe B measured the predicted 2.8-centimeter decrement in its 40,000-kilometer orbit to 0.25% precision.

The satellite also confirmed the frame-dragging effect, in which the rotating Earth twists the surrounding spacetime. It's as if the spinning Earth were immersed in honey, Everitt explained. "When it spins, the Earth will drag the honey with it," he said. "In the same way, the Earth drags spacetime with it." Gravity Probe B confirmed the frame dragging effect, which is less than 1/10 times as pronounced as the geodetic effect, to 19% precision.

Still, that's a far cry from what researchers had hoped to achieve. To measure the two effects, Gravity Probe B tracked the motion of four gyroscopes, comparing the alignment of their axes of rotation with the direction to a reference star. On the probe's polar orbit, the geodetic effect caused the gyroscope axes to cant slightly north-south, whereas frame dragging nudged them east-west. Spinning at 5000 revolutions per minute, those gyroscopes were engineering marvels—almost perfect quartz spheres the size of Ping-Pong balls covered with superconducting

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niobium to produce a magnetic field along their axes. With them, researchers aimed to measure frame dragging to 1% precision.

But electrostatic imperfections in the gyroscopes thwarted that plan. Mechanically, the spheres were the roundest objects ever manufactured, Everitt explained. Were one blown up to the size of Earth, the biggest hill on it would be 3 meters tall. However, trapped charges in the niobium made the gyroscopes far less round electrically; an Earth-sized map of a sphere's voltage landscape would sport peaks as high as Mount Everest. Interactions between those imperfections and ones in the gyroscopes' housing created tiny tugs, and to reach the final precisions, researchers spent 5 years figuring out how to correct for them.

Some other scientists aren't sure how much they trust the corrections. Five years ago, Ciufolini notes, Gravity Probe B researchers were reporting uncertainties more than 10 times bigger. Correcting for such large "systematic errors" is tricky business, he says: "I don't know the details, but it seems to me very difficult to get rid of more than 90% of the systematic error."

The previous measurement also puts a damper on the new results. In 2004, Cifuolini and Erricos Pavlis of University of Maryland, Baltimore County, measured frame dragging by tracking the orbits of the LAGEOS and LAGEOS II satellites, simple reflectors launched in 1976 and 1992 and used primarily to monitor the motion of Earth's surface. By very carefully monitoring which way the planes of the satellites' orbits turned or "precessed," they measured the effect to 10% accuracy, largely stealing the thunder of the Gravity Probe B team in some researchers' opinions. "At best they've just confirmed the work Ciufolini did," says Robert O'Connell, a theorist at Louisiana State University in Baton Rouge. "So I find it a bit too much, all the hoopla" of a NASA press conference, he says.

In the end, Gravity Probe B's full value goes beyond the results of the experiment, Everitt told *Science*. "Why was it worth it?" he says. "Just the element of challenge in it, the element of invention in it. There was this constant challenge of inventing new technologies." He notes that 100 students earned Ph.D.s working on the experiment. Others offer a less favorable assessment. "This [$760 million] was government money," O'Connell says. "And to my mind it was misspent and poorly managed" by the government agencies involved.

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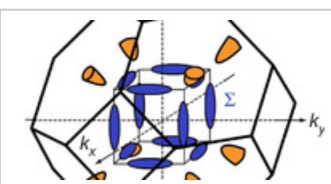

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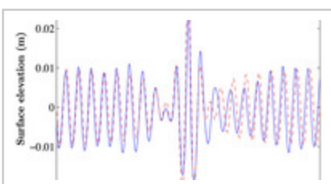

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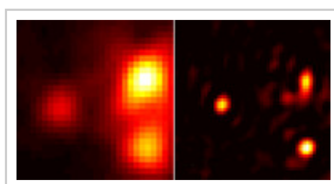

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